Discussion Paper for future Red River Instream Flow Needs Studies

1. Introduction

The work described herein supports the International Red River Board (IRRB) work plan under the "Water Quantity" Strategic Goal and the desired outcome of assessing and recommending a process for the development and implementation of minimum flow criteria for the Red River at the International Boundary.

This document summarizes recent work completed and provides information for the IRRB to make decisions regarding future investigations into the aquatic ecosystem health and instream flow needs of the Red River. Two options are available. One, make very high level assumptions based on the information available and the rudimentary modelling work completed. Two, gather key data and improve and extend the modelling work to better understand the complexity of the Red River's aquatic ecosystem and make more informed low flow management decisions.

The Hydrology Committee recommends the option of improving the science to improve decision making. Several potential studies are outlined for the IRRB's consideration, including:

- Water Usage
- Water Quality
- Bathymetry Survey
- HSI development for the Red River
- Extend the model to include a portion of the USA
- Tie into the telemetry study

2. Summary of Past and Present Work

Over the last ten years, the IRRB has investigated options for apportionment or low flow management of the Red River that includes consideration of aquatic ecosystem health. At the January 2008 meeting, the IRRB approved the Hydrology Committee's (COH) plan to develop and recommend flow apportionment procedure for the Red River. COH has been tasked with establishing future instream flow need criteria for maintaining fish and fish habitat and recommending steps for mitigating potential adverse effects of extreme low-flow conditions on fish, fish habitat and aquatic biota in the Red River in future decades. The work to date includes three published reports and some recent modelling work undertaken by the Hydrology Committee members.

The first report, was completed by Dr. Rob de Loe, University of Guelph, in 2009 and entitled "Sharing the Waters of the Red River Basin: A Review of Options for Transboundary Water Governance". The report reviewed apportionment governance procedures relevant to the Red River Basin (www.ijc.org/en/rrb/sharing-waters-red-river-basin-review-options-transboundary-water-governance). The study was based on an extensive review of two main sources of information: (1) documents and reports relating to water management in the Red River Basin, and (2) the literature of transboundary water management. Two overseas and two International Canada/US case studies were analyzed in

detail, with the goal of revealing insights into real-world problems and solutions of transboundary water governance. The overseas case studies were the Orange-Senqu River Basin in southern Africa and the Murray-Darling Basin, in Australia, The two Canada/US case studies were the St. Mary-Milk Rivers and the Souris River Basins. The study recommended an apportionment model and approach to transboundary water governance in the Red River Basin that includes the following major elements:

1. A prior appropriation to meet critical human and environmental needs.

2. Rules to apportion remaining natural flows between Canada and the United States based on the principle of equitable sharing.

3. Rules regarding waters that originate in the respective countries' portion of the basin but do not cross the boundary. This model represents a balanced approach that takes account of local circumstances (e.g., the role of the *Boundary Waters Treaty of 1909*, existing management relationships, climatic conditions and the nature of water uses).

The second report was prepared by R. Halliday & Associates in 2010 and entitled "Determination of Natural Flow for Apportionment of the Red River" (www.ijc.org/en/rrb/determination-natural-flow-apportionment-red-river-may-2010). The report made recommendations on apportionment procedures suitable for the Red River. The Project Depletion Method was recommended given the availability of an adequate hydrometric network and a robust system of water permits or licenses in the Basin. Information is provided on how the calculation can be accomplished and several information gaps were identified in the areas of hydrometric and meteorological networks; water allocation; water use: evaporation and apportionment. The report notes that there are a number of matters that must be resolved before natural flow can be calculated and before an apportionment arrangement can be executed. However, as water consumption in the Red River Basin is relatively low compared to that in other apportioned basins in the interior plains, the report concluded that it may be preferable to explore whether an international drought contingency plan may be a productive task to pursue rather than considering a traditional apportionment agreement. As an alternative, careful consideration of minimum flow criteria for the Red River could provide additional insights. Such criteria could well be the only element of an apportionment arrangement that is really required at this time.

The third report gathered information to support the development of instream flow needs. A report entitled "Information Available for an Instream Flows Analysis of the Red River for Water Apportionment Purposes" was prepared by William G. Franzin and dated December 2011. The development and implementation of water quantity apportionment procedures for the Red River Basin requires an understanding of the aquatic ecosystem to assist in identifying instream flow requirements for the Red River. Information was gathered with respect to the following five major riverine areas of hydrology; geomorphology; biology; connectivity; and water quality; variables.

Over the last few years, through the IRRB Hydrology Committee, an ad hoc study team of hydrologists and fish biologists from Manitoba Sustainable Development and Department of Fisheries and Oceans Canada undertook an IFN study. The work included the Indicators of Hydrologic Alteration (IHA) method, which is a hydrological method, and the Physical Habitat Simulation (PHABSIM) method, which is a habitat method. The study produced some preliminary results with the information currently available and also identified a number of future studies required to better understand the complexity of the Red

River's aquatic ecosystem. The study completed as much work as possible with the available resources and data. Continuing the work will require additional resources and data.

3. Summary of Recent Modelling

Indicators of Hydrologic Alteration (IHA) Application and Results

Indicators of Hydrologic Alteration (IHA) is a software program that provides ecologists and hydrologists with a tool to assess how rivers, lakes and groundwater basins have been affected by human activities over time or to evaluate future water management scenarios. The method essentially calculates statistics to compare the natural and regulated flow regimes. The IHA method characterizes hydrological regimes using 33 parameters. These parameters are categorized in five main hydrological groups that are based on magnitude, timing, frequency, duration, and rate of change and each group of parameters describes specific ecosystem influences.

A natural hydrograph is required for IHA. To conduct the IHA method, the team investigated existing natural flow information in the Red River. The most recent naturalized flow data was estimated by the USGS in cooperation with the Bureau of Reclamation (USBR). The work is summarized in a USGS report entitled "Historic and naturalized monthly streamflow for selected sites in the Red River of the North Basin in North Dakota, Minnesota, and South Dakota, 1931-2001". Naturalized streamflow was estimated by eliminating the hydrologic effects of Orwell Dam, Reservation Dam, White Rock Dam, Baldhill Dam, surface water withdrawals, and return flows. To obtain daily natural flows at Emerson, the difference between the natural and observed flows was subtracted from the observed daily flow for each month.

Generally speaking the IHA anaylyis found that the deviation from the natural flow was minor. However, the minor deviations are much more pronounced at lower flows. An emergency drought management plan or low flow criteria would likely be sufficient to protect the aquatic habitat. This supports the contention of the R. Halliday & Associates work in 2010.

A better understanding of current water usage in the basin would improve the understanding of how much impact water usage could have on the aqautic habitat at low flows. Better water usage data would be required for an emergency drought management plan or determining low flow criteria.

Physical Habitat Simulation (PHABSIM) Application and Results

Physical Habitat Simulation (PHABSIM) is an IFN method for predicting the impact of physical changes of river flow on fish habitat availability. This tool evaluates discharges and biological preferences of specific species to quantify the proportions of suitable and unsuitable areas of stream reaches.

The PHABSIM modelling was completed using River2D software. River2D was developed by the University of Alberta and is free to use (www.river2d.ualberta.ca). River2D is a two-dimensional, depth averaged, and finite element model used for fish habitat evaluation studies. A River2D model was created for the reach between Emerson and Morris. Since the Assiniboine River will contribute flow at its confluence with the Red River in Winnipeg and the Saint Andrews Lock and Dam increase levels in the

vicinity of Winnipeg, the assessed reach was decided to be the most important for evaluating low flows between jurisdictions.

River2D was used to generate two sets of results for various low flows. One set only considers the area with a certain depth of water. The second set includes the biological preferences for various species present in the Red River and calculates the weighted usable area at various flows.

Depth-area results

The figure below shows the area with water of a certain depth at various flows. Although this information is not directly linked to biological data, if could be used to indicate thresholds where available habitat begins to decline more rapidly and when the river may be more likely to experience increase in temperature and dips in dissolved oxygen. As an example, at flows of 400 cfs or less, there is very little area with 2 meters of depth.
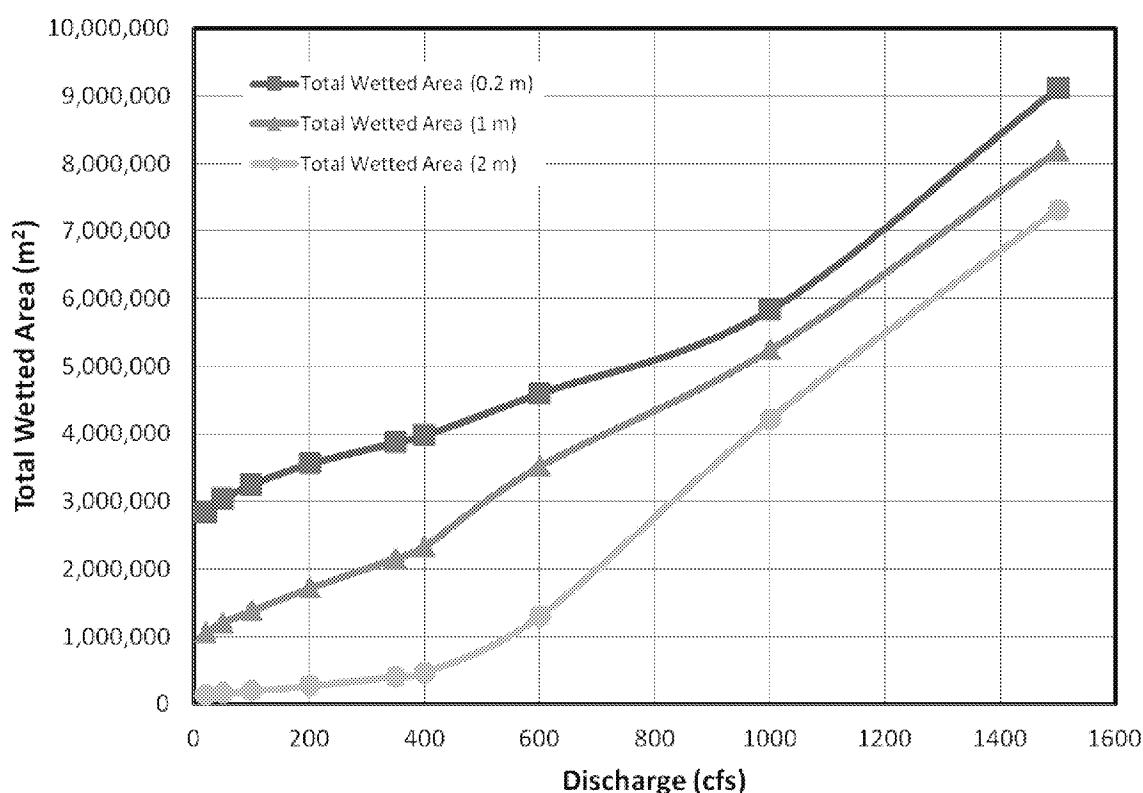
### Weighted Usable Area Results

The Weighted Usable Area (WUA) refers to the weighting of the habitat suitability values of velocity, depth and substrate for a particular fish species and life stage. WUA analysis determines the 'usable' habitat throughout the applied range of flows and this used to set environmentally acceptable flow regimes, usually with an emphasis on maintaining or improving physical habitat availability for instream flow needs. River2D was used to calculate the WUA throughout the applied range of flows for various species at various life stages.

Fish preference data represented as habitat suitability index (HSI) curves were obtained from the Minnesota Department of Natural Resources. The data describe ideal habitat conditions of fish species

and their life-stages within depth, and water velocity ranges in addition to suitability with several varieties of river bed substrates. Fishery habitat biologists of Manitoba Sustainable Development selected nine Valuable Environmental Component (VEC) fish species with relevant life-stages that best reflects spring and summer spawners; cold water and warm water spawners; pelagic and benthic fishes; lotic and lentic species; thereby providing a diverse range of species and habitat diversity associated with the Red River. Two additional mussel species were also included.

The model output showed that many species experience a significant change or drop in the amount of habitat at approximately the 100 to 200 cubic feet per second range. Many curves also showed a decrease in weighted usable habitat as flows increased. In most cases this does not reflect reality. The decrease in habitat with increasing flows could be explained by a few things. The habitat suitability curve may not be appropriate for the Red River. While the main channel may not provide the preferred habitat, fish could still use the river even if more depth and velocity are experienced. Also, with increasing flow the river would be connected to more habitat in the connecting tributaries. For these reasons, higher flows are assumed to have more benefit to the aquatic habitat and more interest was focussed on the drop in habitat as flows decrease.

The weighted usuable habitat for Walleye at various life stages are shown below as an exmple of the output generated with the River2D model.

Walleye Adult

Walleye Juvenile

Walleye Young of Year

Walleye Spawning
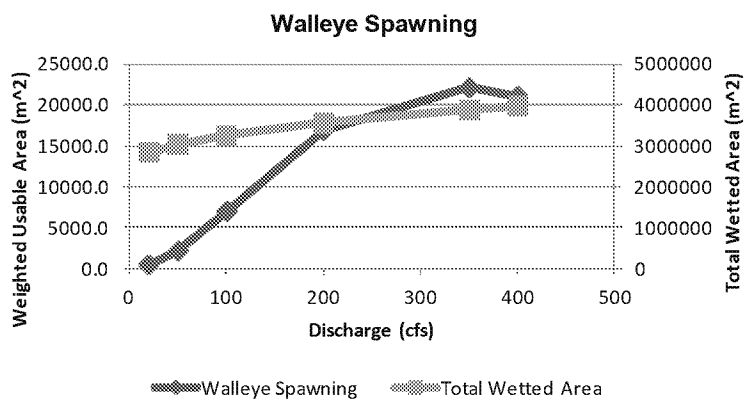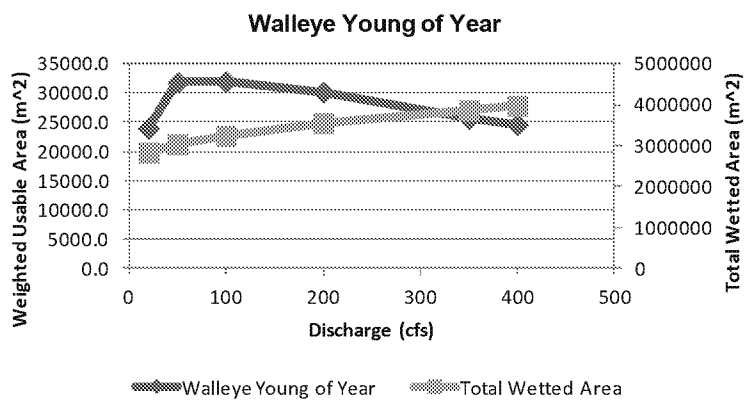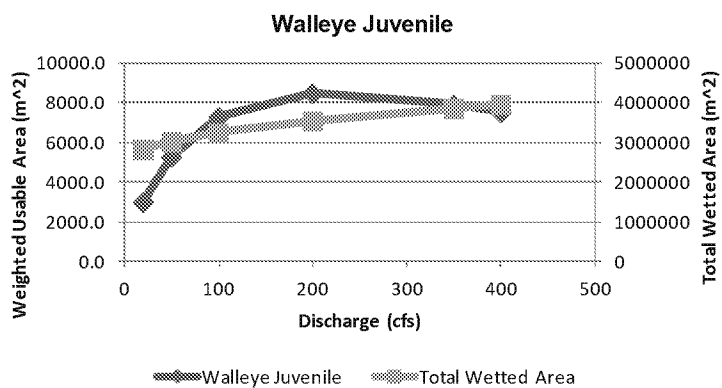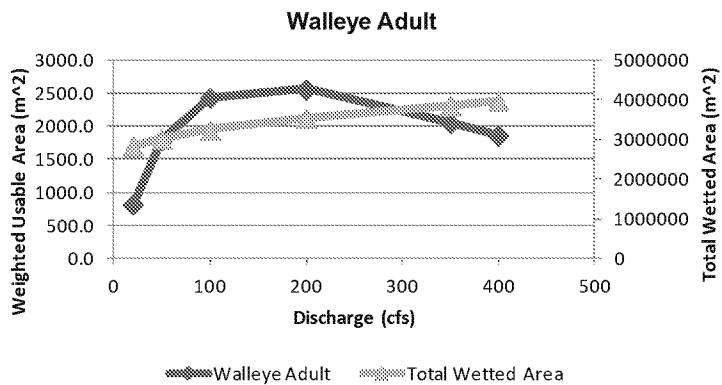
Limitations and data needs

A number of limitations exist for conducting modelling assessment due to various reasons. The limited records of river flow level information during low flow conditions is one of the obstacle to precisely validate models, especially for the desired low flows. Based on the limited information, the substrate is assumed to be silt in the River 2D model. There is also limited bathymetry data, and water surface elevation data during low flows. The Habitat Suitability Index curves were created in Minnesota and not Manitoba and therefore may not be transferrable.

The influence of water quality on the suitability of aquatic habitatat was not included in the modelling work. Low flows are known to make the river more susceptable to periods of high temperatures and low dissolved oxygen.

Habitat suitability criterion that closely describes species of interest's behavior is always emphasized. Outputs must be compared with what is known to occur for the species of interest. Reach mapping is considered a good practice while performing this method, because it helps avoid mistakes in applying the habitat suitability criteria. For instance, fish that typically spawn or rear along river channel margins and floodplains may select for slow, or shallow habitat that the model may indicate occurs at very low discharges in the center of the channel. In fact, only channel margins and overbank areas provide adequate spawning and rearing habitat for these species, and correct interpretation of the results and following recommendations must reflect this biological reality. Thus, validation of the biological output in PHABSIM should be done through observation of fish distribution in the field.

4. Options for IRRB Consideration

Option 1: Determine standards using current Weighted Usable Area Information by PHABSIM analysis

Using the Wetted Usable Area curve
Although the assessment was conducted with limited qualitative and quantitative information, the results from the study indicates some thresholds. These results could be used to estimate low flow criteria for the aquatic habitat. The task would be a collaborative effort between the Hydrology Committee and the Aquatic Ecosystem Health Committee.

Option 2: Additional in-depth studies to

A number of limitations mentioned above hindered precise analysis and assessment in the study. Additional studies to gather key data and improve and extend the modelling work could be undertaken to better understand the complexity of the Red River's aquatic ecosystem and make more informed low flow management decisions. Having improved data and information would provide great opportunities for a proper instream flow needs assessment in the Red River.

Many of the tasks listed below are multi-disciplinary and would require collaboration between the Hydrology Committee, Aquatic Ecosystem Health Committee, and the Water Quality Committee.

Water Quality

Although water quality data in the Red River is available through Environment Canada- Province of Manitoba collaborative monitoring program, the resolutions and locations of the information are not sufficient to conduct an in-depth study. In Canada, water quality in the Red River is monitored by Environment Canada at the Emerson gauging station near the international border. Province of Manitoba also monitors water quality near St. Norbert and Selkirk. In the US, Macek-Rowland and Dressler (2002) provide statistical summaries of water quality data for all of the Red River gauging stations from Emerson upstream to Wahpeton for a considerable 30 year period. Some of these stations have water quality data that extends up to 50 years. The USGS and USBR developed a water quality model to simulate potential effects on water quality from various water supply options including effects of low river flow on dissolved oxygen. The model is applied in the Red River from upstream Fargo to the international boundary.

Therefore, additional monitoring efforts would be required to properly conduct a water quality and low flow combined impact assessment on aquatic species in the Red River.

Bathymetry Survey

The currently available bathymetry data was obtained in 1950s and has been applied in a number of studies on the Red River under an assumption that the river is homogeneous and preserves its sinuosity and channel width. However, in order to properly conduct a physical habitat simulation (PHABSIM) using analysis tools like River2D model, accurate bathymetry information is a critical component for achieve meaningful and successful assessments. Therefore, a new bathymetry survey in the Red River is required to carry-on the study.

HSI development for the Red River

Habitat suitability index (HSI) and habitat suitability curves (HSC) are critical components for the study. However, the curves used in the study are not developed in the Red River, which leads to uncertainty when transferring them to the Red River. Site-specific curves developed for the study area would significantly improve the model performance and provide better understanding for aquatic studies.

Extend the model to cover some USA portion

With additional data, the River2D model could be extended upstream of into the US portion of the river of downstream to the Red River Floodway. This would provide much better understanding on instream flow needs in the Red River Basin. Collecting both bathymetry and HSC curves along the entire span of the Red River from US portion would be critical components for a successful study.

Water Use Data

The Hydrology Committee has drafted an IWI proposal to review water usage across the entire Red River Basin for the period of 1985-2015. This data would provide updated insight into potential low flow management issues including the impact of water use on the aquatic habitat.

A detailed water use information study looking at usage in Minnesota, North Dakota, and Manitoba would also be required for natural flow calculations.

Tie into the telemetry study

Collecting new flow, velocity and substrate data or measurements, particularly at low flow events, in the Red River are critical to accurately carry out the biological component and/or to ground truth the current study findings. Substrate would be best sampled at a low flow to be representative of available habitat at low flow. Behavioral escape responses of fish to lakes, tributaries or deep pools, reflects the availability of deep habitat, need to be addressed especially during the extreme flow events at the Red River through hydrological (hydrographs), water use, or modeling analyses. Link the change in habitat quality and quantity to fish kills; fish population size or productivity needs to be addressed as they are not captured by the current modeling exercise.

APPENDIX – Instream Flow Needs Background

Overview of Instream Flow Needs and River System Function

The structure and function of a river system are based on five riverine components; hydrology, geomorphology, biology, water quality and connectivity. A complete evaluation of instream flow needs will address all of these components, as they each contribute to the health and function of a riverine ecosystem.

Hydrology
Hydrology is the master variable and the central character of rivers that connects and interacts with four other components (Geomorphology, Biology, Connectivity and Water Quality). The notion of hydrology is best described by its four dimensional representation: longitudinal (headwater to mouth), lateral (channel to flood plain), vertical (channel bed with groundwater), and chronological. Hydrologic records are critical for understanding and investigating stream components, in order to assess habitat changes, hydraulic functions, water quality factors, channel maintenance, and riparian and valley forming processes. In addition, hydrologic records are also required to develop hydrologic time series and, if needed, water budgets. The records are collected from stream flow gauges throughout the river, and if some of the data of a sufficient period is missing, several methods are used to estimate hydrology.

Geomorphology
Geomorphology provides information regarding the shape of the channel and the water that flows through and sometimes over it. There are eight channel-forming variables (discharge, sediment supply, sediment size, channel width, depth, velocity, slope, and roughness of channel materials) that interact among one another. The ecological integrity of a river is maintained by the natural flow regime.

Biology
Prior to the implementation of instream flow tools that require habitat-discharge relations, the identification of target species and their habitat requirements are necessary. Common approaches to the selection of target species may involve any one of a number of approaches including single species, mixed species, restriction to obligate riverine species, habitat guilds (Leonards and Orth, 1988, among others) or any combination of vertebrates, invertebrates, and floral components. Several approaches have been developed to derive habitat requirements but most involve some form of habitat suitability criteria that defines some aspect of suitable habitat. When sufficient data are available, fluvial habitat specialists are able to identify habitat bottlenecks that constrain one or more species. These limiting conditions can then be factored into the development of instream flow prescriptions.

Connectivity
Connectivity of a river system in general refers to the flow, exchange, and pathways that move organisms, energy, and matter through these systems. From an Instream Flow Needs (IFN) context, a river system's lateral connectivity is considered critical to the function of large floodplain river ecosystems. Nutrients and organic matter transported from the floodplain to the river encourage the development of aquatic plants, plankton, etc., and, in turn, provide a rich food source for fish. River system vertical connectivity with subsurface groundwater is the source that sustains base flows during dry periods. As well as connecting the river system with the upper and lower parts of the watershed (longitudinal), in order to create a favorable environment for fish and many other aquatic organisms to

migrate within the upstream and downstream of the river to meet a variety of habitat needs. This is especially important in the Red River where climatic conditions change drastically within the year (chronologically).

Water Quality

The amount of flow is one of several factors that affect maintenance of water quality, including the physical, chemical, and biological attributes of water. Chemical characteristics of the Red River are reflected by measurement of pH and dissolved oxygen. Physical attributes of the Red River water quality are assessed through turbidity (mostly sediments) and temperature. Additionally, biological parameters are estimated by analyzing water for any occasional biohazardous materials which may have been introduced into the river by spills. These factors are monitored routinely in the Red River at several gauging stations in the US and Canada.

Types of Instream Flow Need Assessment Methods

Historically, instream flows were based on a basic minimum standard value with no emphasis on the five components of riverine management listed above. While in some applications this may be acceptable, it is becoming more common practice to find a range of flows to help restore rivers to their natural state. Just as there is a range of detail required for various assessments, there is a wide range of assessment tools. All tools have their advantages and disadvantages, their strengths and weaknesses. Many considerations, such as time and data availability, determine whether a particular method is viable or not.

In general, assessment methods can be categorized as follows:

- **Hydrological Methods** - *desktop analysis*:
  Examination of historic flow data to find flow levels that naturally occur in a river and can be considered "safe" thresholds or within the range of natural variability patterns for flow alteration.
- **Hydraulic Methods** - *field-based methods*:
  Examination of change in a hydraulic variable, e.g. "wetted width", as a function of discharge. The change in this examined variable is a proxy for the general quantity of fish habitat in a river.
- **Habitat Methods** - *numerical habitat models*:
  Examination of change in the amount of physical habitat based on selected variables and target species, as a function of discharge.
- **Holistic Framework Methods**
  Examination of flows based on multiple data inputs including expert opinion, leading to recommendations of flow regimes for all components of the riverine ecosystem, which may also include consideration of socio-economic objectives